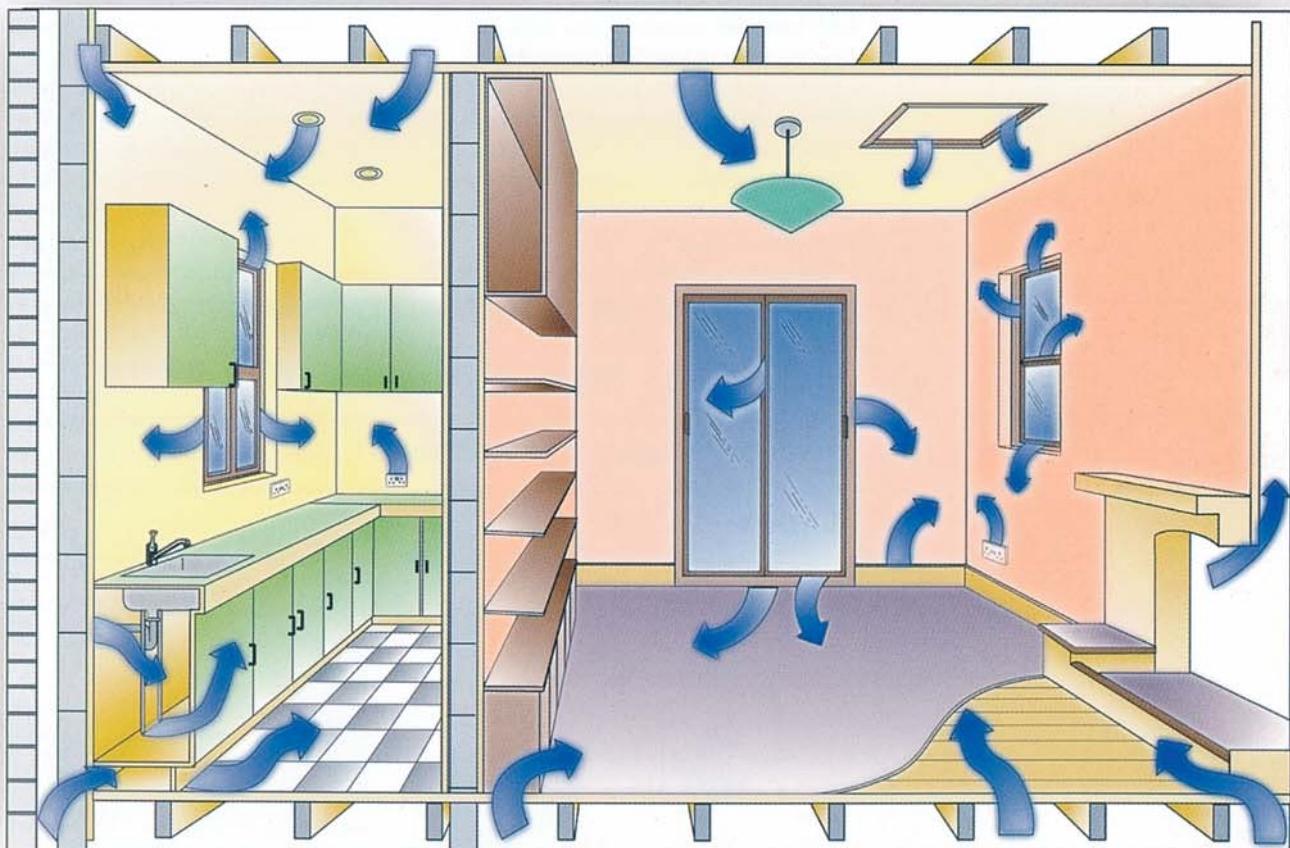


## Improving airtightness in existing homes



ENERGY EFFICIENCY

BEST PRACTICE  
PROGRAMME

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## 1 INTRODUCTION

### INTRODUCTION

The uncontrolled leakage of air through and around the building structure has traditionally provided high infiltration rates in houses. Occupants have therefore been unaware of the need for proper ventilation even though uncontrolled leakage such as this generally leads to unnecessary heat loss and very often to discomfort for the occupants because of draughts. The increasing need for energy efficiency means that airtightness has become an important issue in housing, and current thinking is that houses should be well sealed but with adequate provision for controlled ventilation where required.

Some sealing measures, such as draughtstripping, can be carried out at almost any time, but many of the most significant air leakage paths can only be addressed during refurbishment. This Guide is designed to help specifiers and building contractors take full advantage of the rare opportunities for reducing air leakage. These are presented by all levels of housing refurbishment. The Guide explains how and where air leakage occurs in houses, and suggests methods for improving airtightness which, when combined with controllable ventilation, will improve the energy efficiency of the building and improve the comfort of the occupants.

### Air leakage

Air leakage is the movement of air, both into and out of the building, through cracks and gaps in the building envelope. The paths that the air takes may be the same in whichever direction it moves, but the effect will be very different.

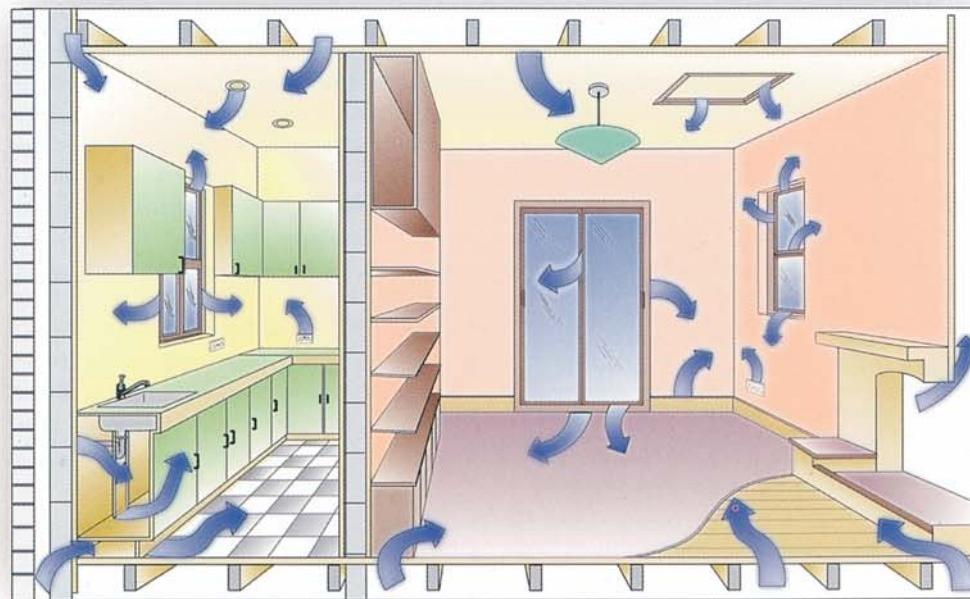
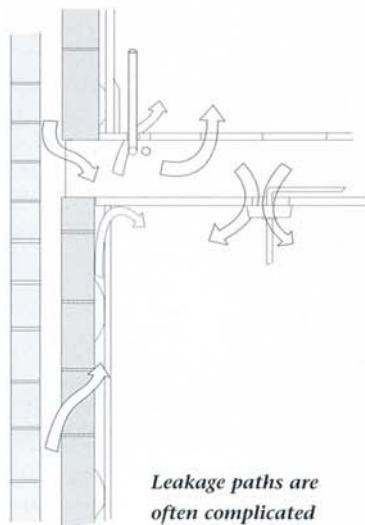
For example, the ingress of cold air through an otherwise insulated wall will result in a localised increase in heat loss and consequently lower surface temperatures. This increases the risk of surface condensation.

Typical air leakage sites are illustrated below. The principal areas through which leakage can occur are:

- joints between structural components, eg floors to walls
- joints around components within walls, eg windows and doors, and through components themselves
- services; both plumbing and electrical
- through porous materials.

While air leakage can occur as a direct leak, for example around opening lights in windows, most leaks follow a more complicated path through a series of routes (as shown right). As a consequence, air leakage can be difficult to trace and seal effectively.

*The majority of UK houses are over-ventilated, but the opportunities for reducing the air leakage are many, and may not be expensive*



## 2 HOW AIRTIGHT?

*'Build tight – ventilate right' means making the building envelope as airtight as practicable and then providing a controllable ventilation system*

### HOW AIRTIGHT?

The level of airtightness achievable in a dwelling will depend on factors such as:

- the type of wall construction and the finish (particular problems can be experienced with dry-lined dwellings, as illustrated in case study 2)
- how well services have been installed
- the age and condition of windows and doors.

The degree of airtightness specified should be to a higher standard where whole-house mechanical ventilation systems are to be used.

The airtightness of a building determines the uncontrolled background ventilation or 'infiltration' rate which, together with ventilation caused by occupancy (opening doors etc), makes up the total ventilation rate measured in air changes per hour (ach). This ventilation rate should be sufficient to maintain an adequate level of indoor air quality while not wasting energy. A rate of between 0.5 ach and 0.7 ach is adequate to control most indoor pollutants and provide sufficient fresh air for the comfort of occupants.

### The need for ventilation

Ventilation is necessary to provide a comfortable and healthy environment by diluting or removing pollutants from within the house. There are many different types and sources of pollution within the home, for example:

- moisture
- volatile organic compounds (VOCs), such as formaldehyde
- house dust mites
- oxides of nitrogen
- carbon dioxide ( $\text{CO}_2$ )
- tobacco smoke.

It is generally accepted that moisture is the most significant of these because of the high rates of generation from activities such as cooking, bathing, laundry, and the problems associated with condensation and mould growth.

To control moisture migration around the house some form of local extraction will be required, the objective being to keep relative humidity levels below 70% most of the time.

The ventilation rates required to provide effective moisture control are higher than would be required to simply provide sufficient oxygen for occupants of the building to breath. As a consequence, the typical ventilation strategy adopted is the rapid removal of moisture at its point of production and the provision of secure, controllable background ventilators, such as trickle ventilators. In addition, openable windows provide the occupants with a means of airing a room rapidly to remove stale air.

If these provisions are to work effectively and in an energy-efficient manner then air leakage must be minimised as a first step to providing controllable ventilation.

The concept of 'build tight – ventilate right' means making the building envelope as airtight as possible and then providing a controllable ventilation system.

## HOW AIRTIGHT?

As ventilation rates are very difficult to measure under normal conditions, air leakage rates at an applied pressure of 50 Pascal (Pa) are often quoted and specified (see box). Suggested ventilation rates for different ventilation options are given in table 1. These rates can be measured using a pressure test as outlined in the box on the right.

Ventilation options	Target pressure test air leakage rate
Local extraction and background ventilators	5-7 ach at 50 Pa
Whole-house ventilation systems	4 ach at 50 Pa or less

Table 1 Suggested pressure test leakage rates for different ventilation options

### FAN PRESSURISATION

The fan pressurisation technique was devised to measure the airtightness of the building envelope. The pressurisation test uses a fan mounted into a dummy door to induce both positive and negative pressure differences across the building envelope while measuring the air flow through the fan. The air leakage rate can then be calculated and quoted for a standard 50 Pa pressure difference. While the results are measured in terms of air changes per hour (ach), similar to ventilation rates, the pressure differentials are several times greater than occur in practice. The results are not therefore directly comparable ventilation rates. BRE has developed a recommended procedure for measuring the airtightness of dwellings<sup>[1]</sup> which allows the results to be used for:

- comparing the relative airtightness of the dwelling with recognised standards
- identification of air leakage paths and the rate of air leakage
- an assessment of the potential for reducing air leakage within a dwelling
- measuring the improvement following airtightness work.

## 3 METHODS AND MATERIALS

### METHODS AND MATERIALS

#### Identifying opportunities

The opportunities for improving airtightness will depend on the extent of refurbishment work being undertaken (as shown in table 2), but even minor redecoration or general maintenance can present opportunities.

Where possible, the first step should be to carry out a fan pressurisation test (see box above) to establish air leakage levels for the house type. It is not normally feasible to carry out tests on all houses. A sample of houses where different forms of construction have been used will normally identify the key air leakage routes which can then be sealed in all similar houses being refurbished.

Where practicable, the seal or 'air barrier' should be formed on the internal surface of the external walls because it is often simpler to gain access to these areas, and the working conditions are less severe.

	Minor works	Major works
Draughtstrip loft hatch and fit securing bolts	✓	
Draughtstrip opening lights and external doors	✓	
Seal around windows and door frames	✓	
Seal service holes through timber floors	✓	
Seal service penetrations through ceilings	✓	
Seal all remaining plumbing services	✓	
Seal all joints in heating ductwork (where possible)	✓	
Seal all electric services including faceplates	✓	
Hardboard across timber floors and seal to skirting		✓
Install injected cavity wall insulation		✓
Seal air space behind plasterboard dry-lining		✓
Seal top and bottom of stud partitions		✓
Add a draught lobby to exterior doors		✓

Table 2 Opportunities for reducing air leakage

## METHODS AND MATERIALS

When designing solutions, consider the long-term life of the building to ensure that airtightening works carried out are not subsequently undone by future alterations or repairs such as lifting floor boards or re-routing of cables and pipes.



**It is vital to remember that rooms with open flue appliances, such as gas fires, require a direct fresh air supply for the safe operation of the appliance. A separate provision for such a supply should be made, and a combustion product spillage test undertaken when airtightening work is being carried out.**

### Sealing materials

When selecting sealants, consider:

- the size and irregularity of gaps
- adjacent materials, likely adhesion and compatibility
- ease of access for application
- joint movement
- durability.

The British Standards Institution publication 'Guidance on selection of constructional sealants' (BS 6213) gives advice on the choice and application of sealants.

The performance of all joint sealants is improved where a backing can be provided to support the seal.

For small cracks and gaps of 2 mm-5 mm, sealant applied through a gun is normally most suitable. Sealants are available in a range of colours, or can be decorated, and have good adhesion qualities to a wide range of materials.

For larger cracks and gaps an expanding polyurethane foam is most suitable. This is typically supplied in cans. Once set, the foam can be trimmed flush to adjacent surfaces if necessary. The expansion of the foam can be many times its original volume and therefore sufficient space must be available in the joint to allow for the foam expansion. Hardening of the foam is initiated by the surrounding moisture (in the air or building fabric) and it is typically cured within a few hours. Manufacturers' instructions should be followed when handling the material to avoid allergic reactions.

For much larger gaps, bagged mineral wool can be useful for packing around components. A polythene sheet can be taped over openings prior to finishing off with plywood, plasterboard or similar material.

## 4 ACHIEVING AIRTIGHTNESS



Expanding foam can be used to seal services

### ACHIEVING AIRTIGHTNESS

#### Windows and doors

The most appropriate type of seal will depend on the type of frame and size of gap. Draughtstrips should comply with BS 7386 '1990 specification for draughtstrips for the draught control of existing doors and windows in housing'. Guidance on draughtstripping can be found in Good Practice Guide 139, 'Draughtstripping of existing doors and windows' (GPG 139). In addition to sealing the opening lights, a suitable sealant should be applied between the frame and the wall opening. This is particularly important with replacement window frames (see case study 2, page 9).

#### Loft hatches

As with windows and doors, seals should be applied around all loft hatches, and the hatch provided with a catch to hold it down securely against the seal.

#### Plumbing and heating services

All gaps around pipework should be sealed through both walls and floors. For a moderate-sized gap, an expanding polyurethane foam may be suitable. For larger holes, bagged mineral wool compressed into the hole is effective.

An internal soil and vent pipe (SVP) can be an easy route for air to move from the ground floor

## ACHIEVING AIRTIGHTNESS

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through the first floor construction and into the roof void. To limit this air movement effectively it is important to form seals at every location where the SVP passes through a floor/ceiling. The sealing method selected should take account of the thermal movement that is likely to occur.

It is equally important to seal every hole where pipes pass into the first floor construction. Air can easily pass through the floor void and into the wall cavity via cracks around joist ends and poorly filled mortar joints.

Cracks and gaps around boiler flues should be sealed with mineral wool capable of withstanding the locally high temperatures.

Ducted warm air systems should be carefully inspected by removing the duct grilles and ensuring that the duct is sealed to the back of the grille with foil duct tape.

### **Electrical services**

As with plumbing services, all cracks and gaps around electric fittings should be sealed. Sealing behind electrical backplates and holes in the plate before they are fixed will reduce leakage through the fitting and allow faceplates to be removed without disrupting the seal. Particular attention should be paid to fittings into dry-lining because the cavity behind the plasterboard provides an easy air path, particularly when the mortar joints in the inner leaf have been poorly made. Injection of expanding polyurethane foam around all sides of the fitting to fill the cavity will help to reduce leakage.

### **Timber ground floors**

Suspended timber ground floors can leak, especially when boards have been lifted for work to be carried out and then refitted poorly. Laying hardboard or plywood over the whole floor area can be effective in reducing leakage provided that the boarding is sealed to the skirting. This will be most effective when the boarding is laid beneath the skirting prior to sealing. The selected sealant must be sufficiently flexible to accommodate floor movement.

In some situations (particularly with older pine skirting) substantial air leakage can occur between the

skirting and the wall. It is therefore advisable that gaps along the top edge of the skirting are also sealed.

Always ensure that adequate subfloor ventilation is provided by way of airbricks.

### **External walls**

The resistance to air movement through an external cavity wall can be improved by the installation of an injected cavity insulation. The insulation increases the resistance to air movement and increases the effective length of the leakage path. Guidance on selecting and installing injected cavity wall insulation can be found in Good Practice Guide 26, 'Cavity wall insulation in existing housing' (GPG 26).

Dry-lining is especially difficult to seal, particularly if damaged or obscured by internal fixtures. A reduction in air leakage can be achieved by using expanding polyurethane foam around the perimeter of the walls and windows to seal the air space immediately behind the plasterboard. Holes need to be drilled around the perimeter of the wall/window at 100 mm intervals and the foam injected to form a continuous seal.

A wet-plastered wall is likely to be more airtight than dry-lined construction.

### **Internal walls**

Studwork internal partitioning can provide a route for air to move through easily, and all services passing through it should be sealed, as described previously. Built-in cupboards, particularly into room-in-the-roof constructions, provide numerous routes for air movement. Sealing joints internally can be effective in reducing air movement.

### **Chimneys**

Disused chimneys should be blocked up and provided with a small grille to ventilate the chimney. A ventilated weatherproof hood should be fitted on the chimney stack.

### **Draught lobbies**

If feasible, a draught lobby should be added to external doors to act as a buffer space and reduce direct air leakage. Any existing porch or lobby should be retained.

## 5 CASE STUDY 1 – ARCHES HOUSING LTD, SHEFFIELD

# Case Study

Since the 1980s, Arches Housing Ltd has been producing affordable energy-efficient accommodation for its tenants. Its aim has been to insulate to as high a degree as possible. The company has also recognised the importance of considering air leakage pathways when refurbishing its stock.

The Arches Housing refurbishment specification is presently being upgraded to include measures which improve the airtightness of dwellings. In particular, it hopes to be able to incorporate pressure testing of 10% of its future refurbishment projects (as it does in its new build work), and to achieve air leakage rates of about 7 ach at 50 Pa. This figure has been based on the pressure testing results of its new build schemes.

Arches Housing Ltd regards the airtightness of a dwelling as a measure of its build quality. In addition, it recognises that the degree of air leakage is often dependent on the standard of workmanship, so it is important that the foreman on each refurbishment scheme is aware of the air leakage specifications.

### House construction

This case study concerns the refurbishment of an early Victorian building constructed of 9-inch brickwork, in the Burngreave area of Sheffield. This property originally consisted of two semi-detached, three-storey houses, which had been modified into a hostel. It was refurbished to convert it into eight self-contained flats. Due to the structural alterations being carried out, the refurbishment work was undertaken while the building was unoccupied.

### Refurbishment package

The programme of work included:

- 200 mm blown cellulose fibre in the roof voids, or 50 mm extruded polystyrene on the sloping ceilings in the rooms in the roof
- timber windows with low-emissivity double glazing, solid timber doors, all draughtstripped

- low-energy lighting
- heating and hot water to all flats provided by two gas condensing boilers incorporating thermostatic radiator valves (TRVs) and room thermostats
- 50 mm insulated dry-lining on external walls
- where ground floors are suspended or situated above the cellar, netting was placed on the underside of the floor and blown cellulose fibre installed between the joists; otherwise the floating concrete ground floor was insulated with 75 mm expanded polystyrene (25 mm at the edges).

For suspended ground floors, netting was placed on the underside of the ground floor, and blown cellulose fibre installed between the floor joists. Blown cellulose fibre is preferred by Arches Housing to mineral fibre quilt. It was also thought likely that air leakage would have been improved using the former material because it forms a dense mass when it is blown in wet.

Specific airtightness measures included:

- using mechanical fixings to install the windows, and expanding polyurethane foam to seal the 10 mm gap around the perimeter; dry-lining up to window frames, then internally sealing around windows using a fixing agent
- sealing the edges between the dry-lining boards
- draughtstripping loft hatches and incorporating bolts to secure the hatches tightly
- sealing around electrical backplates
- sealing all gaps around plumbing services with expanding polyurethane foam
- sealing floorboards with sealant or hardboard where floorboard gaps were wide.

Pressure tests were carried out shortly before completion and an average air leakage rate of 10 ach at 50 Pa was achieved, although this was expected to improve when hardboard was laid over floors in some flats as part of a flooring contract.

## 6 CASE STUDY 2 – DERWENTSIDE DISTRICT COUNCIL

This case study concerns a trial\* undertaken as part of a refurbishment programme on a number of local authority houses in County Durham.

### House construction

The properties are two-storey dwellings built during the 1960s with uninsulated cavity walls (of either brick-block or block-block construction) lined internally with plasterboard-on-dabs; solid concrete ground floors, and low-pitched trussed roofs. The houses were built as staggered terraces, and each dwelling had a single-storey flat roof extension.

In parallel with this trial, a refurbishment package was also carried out on the properties by Derwentside District Council to reduce the energy consumption of the dwellings. This included:

- blown fibre cavity wall insulation
- new windows with trickle ventilators
- new doors with draughtstripping
- increasing loft insulation to 250 mm
- replacement of solid fuel heating with gas-fired combination boiler.

### Airtightness programme

A series of fan pressurisation tests were conducted at various stages of the work. Of the 12 houses involved in the scheme, all received a standard package of airtightness measures, while half received more targeted airtightness work.

The standard package measures included:

- injecting expanding polyurethane foam into the gap around windows and doors to prevent air leakage from reveals
- external mastic seal to all window and door frames
- injecting expanding polyurethane foam in continuous ribbons, between the plasterboard finish and inner leaf blockwork, in order to prevent air leakage into this cavity from the first floor void or from interior partitions; this entailed drilling rows of 9 mm diameter holes at 100 mm intervals around the edges of the plasterboard on external and party walls and window openings.

The targeted airtightness package consisted of:

- draughtstripping windows and external doors
- adding extra internal mastic sealing between plasterboard and window, and between plasterboard and external door frames
- draughtstripping of loft hatch
- sealing around electrical sockets
- sealing around the boiler
- depressurising each targeted house to identify the leakage paths, which were then sealed.

### Results and conclusions from the trial

This programme significantly reduced the air leakage characteristics of houses in the trial from an average of approximately 25 ach at 50 Pa to between 8.5 ach and 13.5 ach. Although this is outside the desired standards (table 1, page 5) the houses were extremely leaky to begin with, and the nature of the refurbishment prevented some measures from being carried out. The fan pressurisation tests determined quantitatively the contribution to air leakage reduction of the various measures. In addition, evidence of workmanship problems was also identified (for example, during boiler installation).

The most significant airtightness measure undertaken was sealing the external walls. The contribution to airtightness from minor works, such as sealing electrical sockets, boiler flue and loft hatches, was modest, but in a more airtight dwelling with a more stringent airtightness target, these would be significant.

The retention of existing kitchen and bathroom units at Derwentside posed significant airtightness problems. Details such as soil stacks provided major air leakage routes, which were extremely difficult to isolate.

When installing the new boiler, plasterboard was often cut away so that the mounting plate could be attached directly to the masonry. Care was needed when sealing around this plate before the boiler was installed, in order to provide an airtight seal.

# Case

# Study



\*The trial was undertaken by Leeds Metropolitan University to examine the ventilation options in local authority dwellings.

## 7 CONCLUSIONS/RECOMMENDATIONS

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### CONCLUSIONS/RECOMMENDATIONS

The majority of UK houses are over-ventilated. The opportunities for improving the air leakage characteristics are many and need not be expensive.

Improving the airtightness of a house must be undertaken as part of an overall strategy for providing energy-efficient ventilation. Carrying out airtightening work must not compromise indoor air quality or cause problems of condensation.

Including airtightness measures within general maintenance and refurbishment specifications will

bring benefits in terms of reduced heat losses, with improved energy efficiency and thermal comfort by the reduction of draughts. Specifications should establish air leakage rates to be achieved depending on the ventilation strategy adopted. Specifications should also make tradesmen responsible for carrying out air sealing work in conjunction with the other tasks they are performing.

Many of the techniques suggested in this Guide are applicable to both new build and existing houses. Further guidance for new build is available in Good Practice Guides 93 to 97 (see below).

## FURTHER READING

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### REFERENCE

- [1] Stephen RK. 'Determining the airtightness of buildings by the fan pressurisation method: BRE recommended procedure'. Occasional Paper PD57/88. BRE, Garston, 1988

### FURTHER READING

British Standards Institution. BS 6213 'Guidance on selection of constructional sealants'. BSI, London, 1982 (amended 1987)

British Standards Institution. BS 7386 '1990 specification for draughtstrips for the draught control of existing doors and windows in housing'. BSI, London, 1990

### DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given on the back cover.

### General Information Leaflet

- 9 Domestic ventilation

### Good Practice Guides

- 26 Cavity wall insulation in existing housing
- 93 Energy efficiency in new housing. Detailing for designers and building professionals. Key detailing principles
- 94 Energy efficiency in new housing. Detailing for designers and building professionals. Ground floors
- 95 Energy efficiency in new housing. Detailing for designers and building professionals. External cavity walls
- 96 Energy efficiency in new housing. Detailing for designers and building professionals. Windows and external doors
- 97 Energy efficiency in new housing. Detailing for designers and building professionals. Pitched roofs
- 139 Draughtstripping of existing doors and windows
- 155 Energy efficient refurbishment of existing housing – a refurbishment guide for housing associations and landlords

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